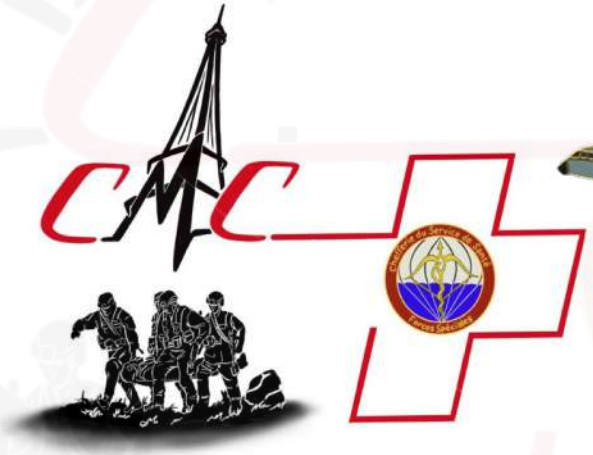
MEDICAL SUPPORT OF HIGH-ALTITUDE MILITARY PARACHUTING



21/10/2022

4ème AMS - Bayonne
1ère CSS-FS
SSA FRANCE

PLAN

1. **High-Altitude (HA) military parachuting**
   - ✓ Definition
   - ✓ Environmental constraints

2. **Environmental pathologies**
   - ✓ Stress
   - ✓ Extrem temperature range
   - ✓ Altitude hypobaria pathologies

3. **Medical regards for prevention & treatment**

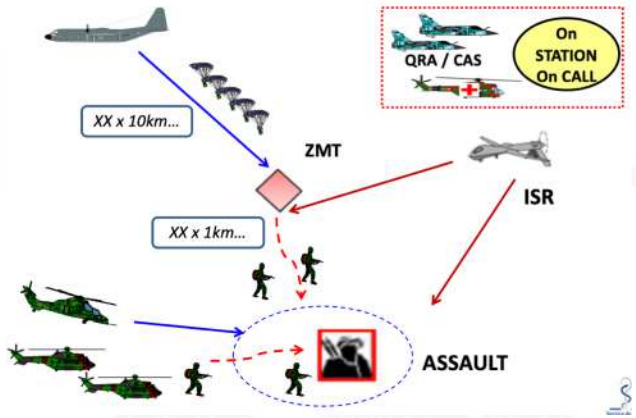
4. **Precautionary principle Vs tyranny of standards**

Morand et al,, The medical constraints of high altitude for the military parachutist at very great height. International review of the Armed Forces Medical Services, , 2021

HIGH-ALTITUDE MILITARY PARACHUTING

✓ How does it usually work ?

- HA High Opening HAHO > HALO Low Opening
- By night for operationnal use
- Piloting the canopy according his flight plan until landing zone



✓ Why using <u>HA</u> parachuting ?

- The highest & the farthest your aircraft fly, the stealthiest you are
- The higher you jump, the farther you can land

➢ **Safety & Tactical advantage**

➢ **Just a 3D way of tactical infiltration for a operation on the ground….**

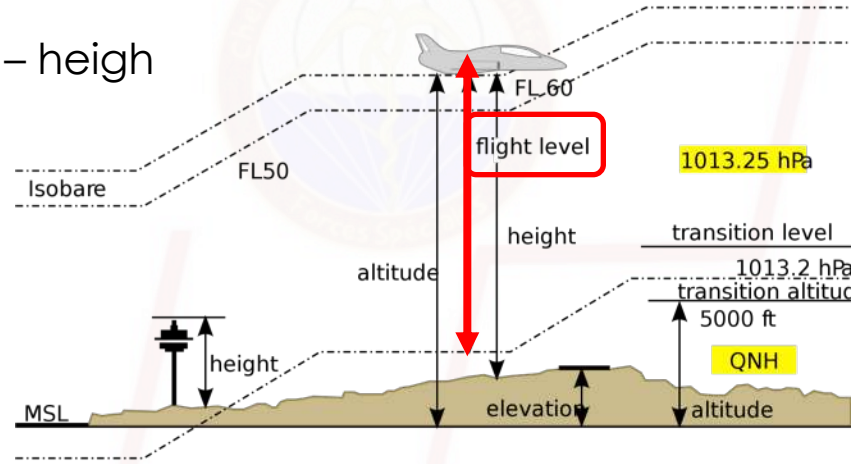
Service de santé des armées

✓ Activities at High-Altitude (HA) :

- **> FL 120**
- *France = très grande altitude SOTGH (vs grande altitude SOGH)*

✓ Altitude reference = Fly Level (FL) :

- Standard of aeronautical measurement
- Altitude pression instead of Altitude – heigh
  - 1hPa ≃ 28 ft
- **FL =** Altitude-Pression / 100
  - ➢ 1 feet (ft) = 0,3048 meter (m)
  - **FL 120 ≃ 12 000 ft = 3650m**

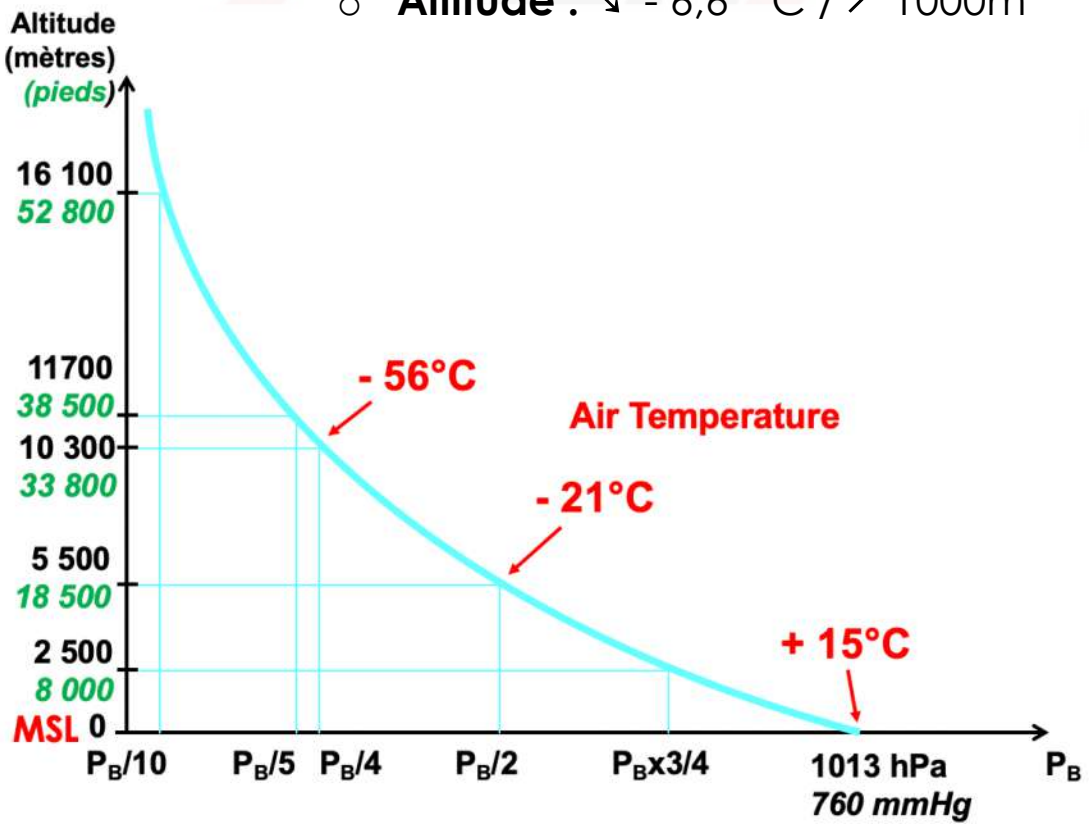


ENVIRONMENTAL CONSTRAINTS OF HA

When you climb, everything decreases, except the stress !

- **Hypobaria :** ↘ atmospherical / barometrical pressure (Pb)

- **Temperature**
  - **Altitude :** ↘ - 6,6° C / ↗ 1000m ➔ *FL120 (≃3650m) : ≃-11 ° C*



➔ **ENVIRONMENTAL PATHOLOGIES**

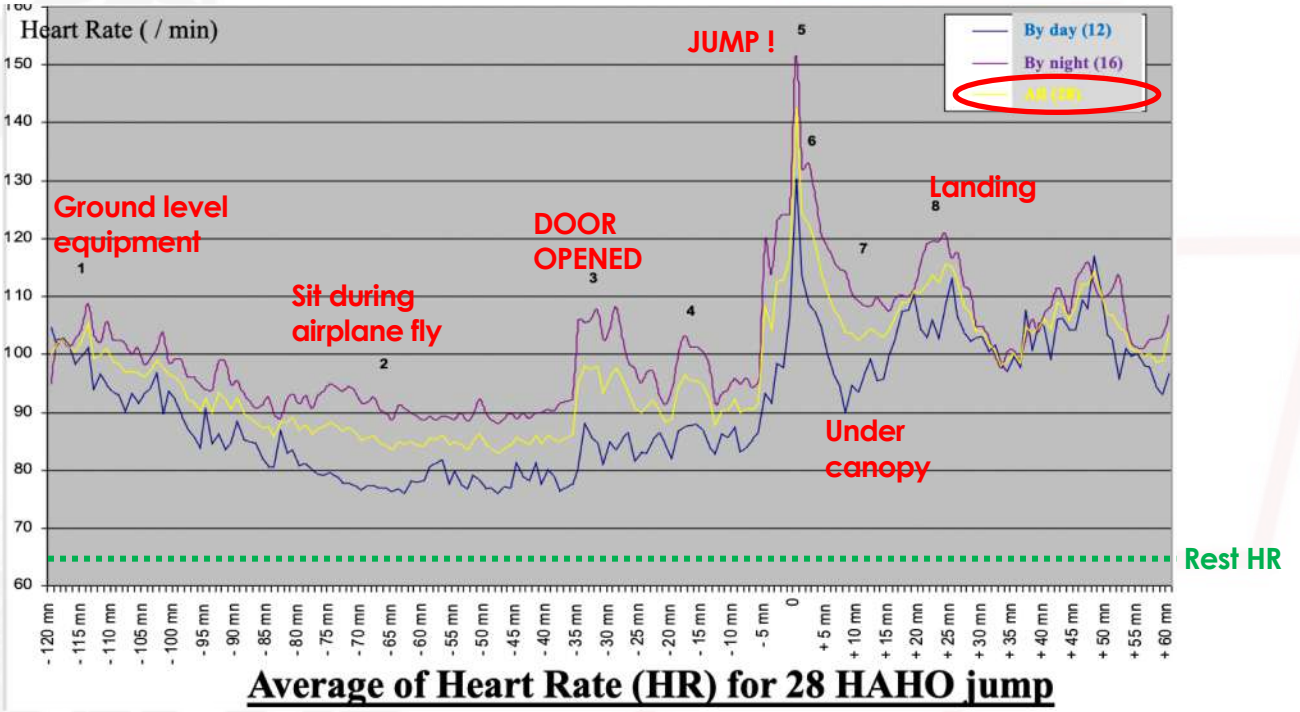
ENVIRONMENTAL PATHOLOGIES

✓ STRESS

- Heart Rythm ↗ at each relevant moment & in complicated conditions
- Increasing of HR mitigated with HAHO training & experience

➔

Psychic exhaustion at the beginning of a war operation



Aigle et al, Stress au cours du saut en parachute à très grande hauteur. Médecine et Armées. 2006

Prevention of stress concequencies ??? :
Medical & military selection

ENVIRONMENTAL PATHOLOGIES

✓ HYPOTHERMIA & FROSTBITES

- Even if T° at ground level is 50° C…
- Reinforced by **« wind chill » effect**

- *Non specific of parachuting*

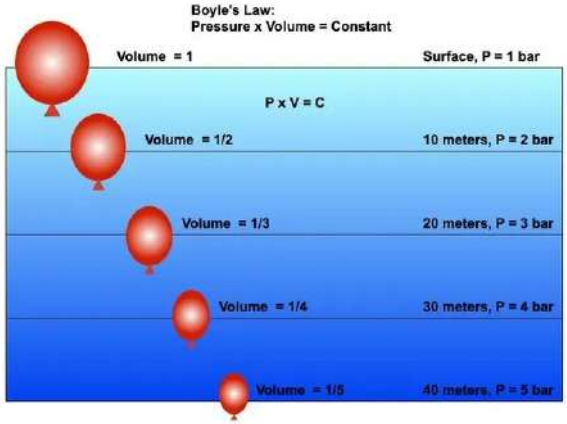
Gruppo et al, Ocular Problems in Military Free Fall Parachutists, Military Medicine ,2002

BASIC PRINCIPLES OF GAS EXCHANGE

✓ **Boyle-Mariotte's laws**

- Pressure x Volume = Constante

➢ **If FL ↗, Pb ↘ , air volume ↗ too**



Air is a liquid

Stable air composition :
O2 ≈ 21% N2 ≈ 78%

BASIC PRINCIPLES OF GAS EXCHANGE

HYPOBARIA PATHOLOGIES

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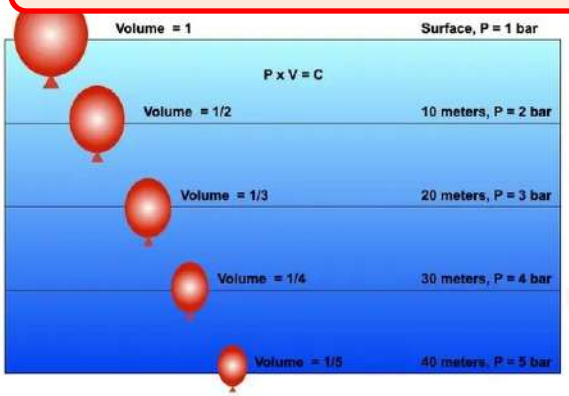


Barotrauma

Decompression Illness (DCI)

Air is a liquid

Stable air composition :
O2 ≈ 21% N2 ≈ 78%

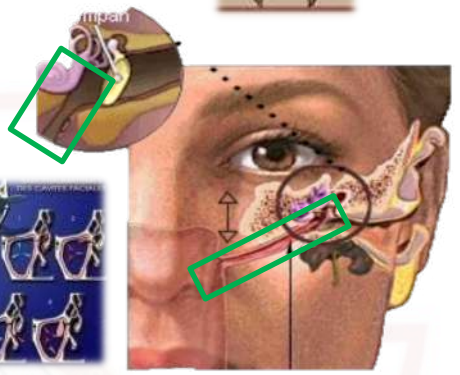
ENVIRONMENTAL PATHOLOGIES

✓ BAROTRAUMA

- Dental pain / aeroodontalgie until tooth fracture

- Sinusal & otitis barotrauma

(acute or chronic eustachian tubal non-permeability)



- Pulmonary barotrauma

Severe but rare

Table 1 Cases of pulmonary barotrauma during rapid decompression training in hypobaric chamber. PTX, pneumothorax

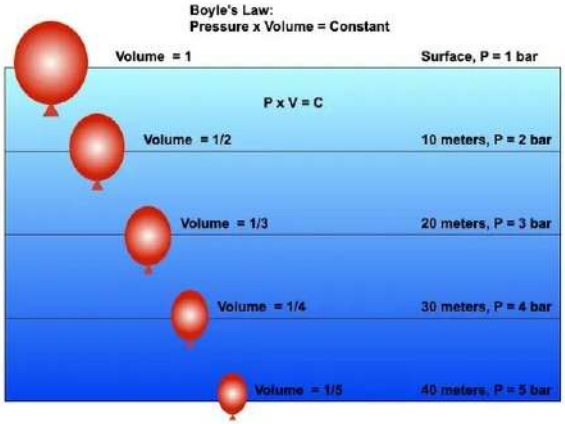
Study/Year	Type of pulmonary barotrauma	No. of subjects	Decompression in feet
Clark 1945 [9]	pneumomedistinum	2	from 8,000 to 31,000
Luft 1954 [10]	PTX	1	from 8,000 to 30,000
Holmstrom 1958 [11]	Pneumomediastinum, PTX, subcutaneous emphysema	2	from 8,000 to 22,000
Cable 2000 [12]	pulmonary barotrauma with cerebral arterial gas embolism	1	from 8,000 to 25,000

Tlapák et al, BMC Pulmonary Medicine, 2020

Prevention of barotrauma ??? :

Selection & medical check before becoming HA parachuting-qualified

BASIC PRINCIPLES OF GAS EXCHANGE



✓ Boyle-Mariotte's laws

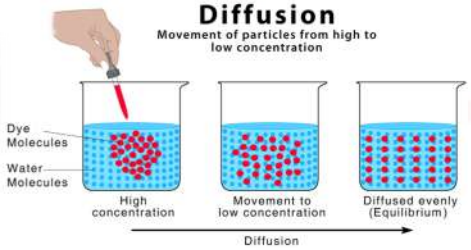
- Pressure x Volume = Constante
  - ➢ **If FL ↗ , air volume ↗ too**

✓ Dalton's law

- Pb = Σ Ppi *(partial pressure of each gas in air mix)*
- Ppi = Pb . Fi *(fraction of each gaz inside air mix)*
- Σ Fi = 100%
  - ➢ Pb = Σ Ppi = Σ (Ppi/Fi)
  - ➢ **If FL ↗, Pb ↘ & each Ppi (PpO2, *PpN2*) ↘**

✓ Diffusion's law

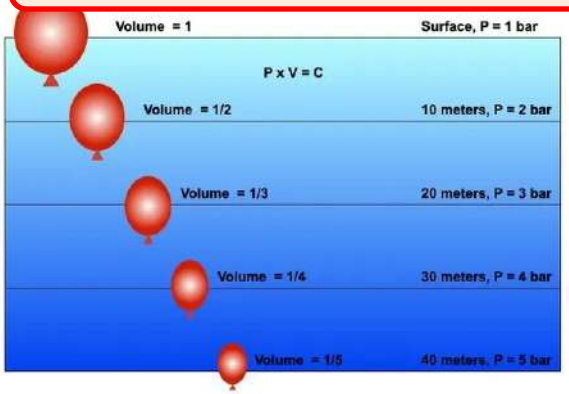
- Movement of a substance from high to low concentration



Service de santé des armées

BASIC PRINCIPLES OF GAS EXCHANGE

HYPOBARIA PATHOLOGIES



Barotrauma

Decompression Illness (DCI)

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Hypoxia

Decompression Illness (DCI)

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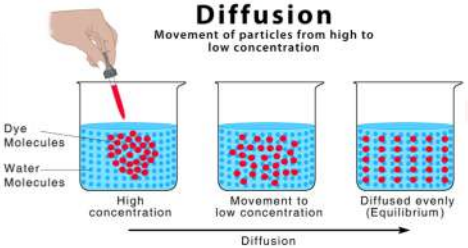
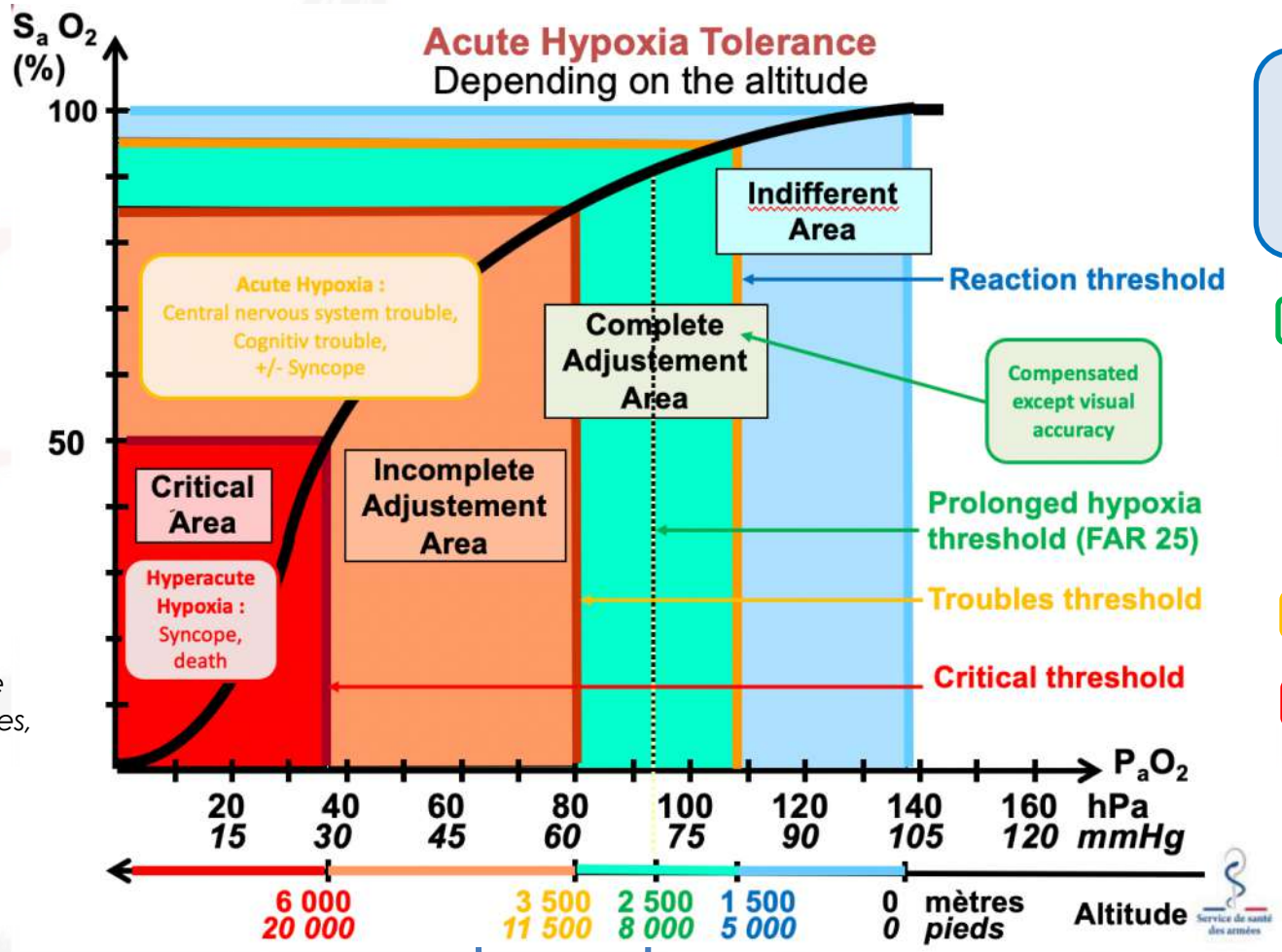


Hypoxia

Decompression Illness (DCI)

ENVIRONMENTAL PATHOLOGIES

✓ ALTITUDE HYPOXIA



Dr Koulmann,
Institut de Recherche Biomédicale des Armées, SSA France

Delays before signs

Few hours

Few minutes

Few seconds

Temporarily acceptable vs Too dangerous ?

Service de santé des armées

❖ Symptoms of hypoxia :

- Kind of symptoms depand on the individual
- Reproducible for everyone

Table 2. *Common Symptoms Associated with Hypoxia.*

Common Symptoms	
Tingling	Shortness of Breath
Hot Flashes	Blurred Vision
Cold Flashes	Nausea
Dizziness	Apprehension
Tunnel Vision	Pressure in Eyes
Trouble Concentrating	Fatigue
Light Dimming	Lack of Coordination
Euphoria	Headache

Impaired judgment

➢ *If you know & indentify your own first hypoxia symptoms during TUC, you diagnose your hypoxia and are able to treat that.*

Philips et al, Hypoxia: Exposure Time Until Significant Performance Effects - NAMRU-D REPORT n ° 16-19 – mars 2016

Table 1. *Standard Time of Useful Consciousness Values.*

Effective Performance Time at Altitude		
Altitude (m)	Altitude (ft)	Effective Performance Time
5,500	18,000	15 min
6,700	22,000	10 min
7,600	25,000	3 to 5 min
8,500	28,000	2.5 to 3 min
9,100	30,000	1 to 2 min
10,700	35,000	30 sec to 1 min
12,200	40,000	15 to 20 sec
13,100	43,000	9 to 12 sec
15,200	50,000	9 to 12 sec

Prevention of Hypoxia ??? :

Individual hypoxia symptoms card

Avoid lack O2

❖ Low prevalence of altitude hypoxia in airborne operations

- No case reports for parachuting, only accidental cabin depressurization or O2 system failure *(2 hypoxia in 47 accidental depressurization in 21 years in Canada)*
- Depend on FL of the drop & TUC
- Starting from the drop, altitude ↘ so TUC ↗ & risk of severe hypoxia ↘
- SoF : rustic & trained military
  limited exposure until the drop

- ***2018 French pre-study in French SOF at FL140 without O2 vs FL120 (Dr Coz)*** :

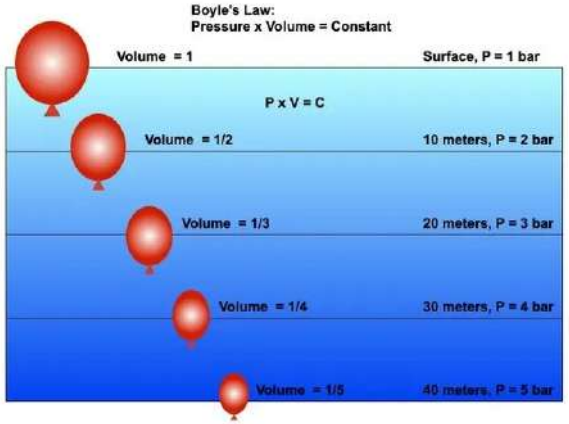
  20 SOF parachutists, 13 Aircraft CrewMembers (ACM) ➔ 3 flies & drops

  Parachutists : no difference found with FL120 drop

  ACM : 70% differences found with FL 120 drop (tiredness & tachycardia)

Service de santé des armées

BASIC PRINCIPLES OF GAS EXCHANGE



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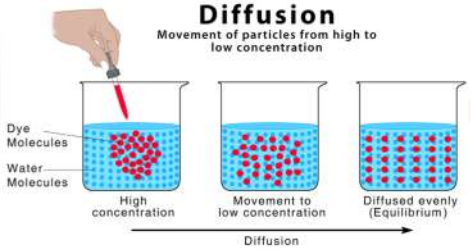
✓ Henry's law

- Amount of a dissolved gas in a liquid is proportional to Ppi inside

✓ Diffusion's law

- Movement of a substance from high to low concentration



Service de santé des armées

BASIC PRINCIPLES OF GAS EXCHANGE

HYPOBARIA PATHOLOGIES

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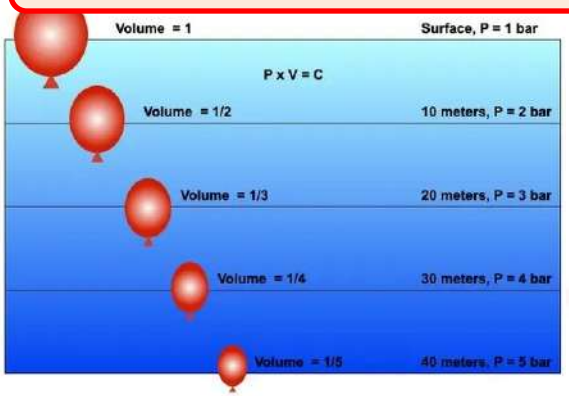

Barotrauma

Decompression Illness (DCI)

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Hypoxia

Decompression Illness (DCI)

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Decompression Illness (DCI)

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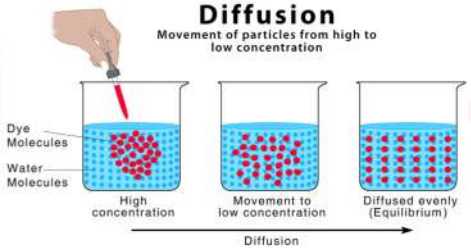


Hypoxia

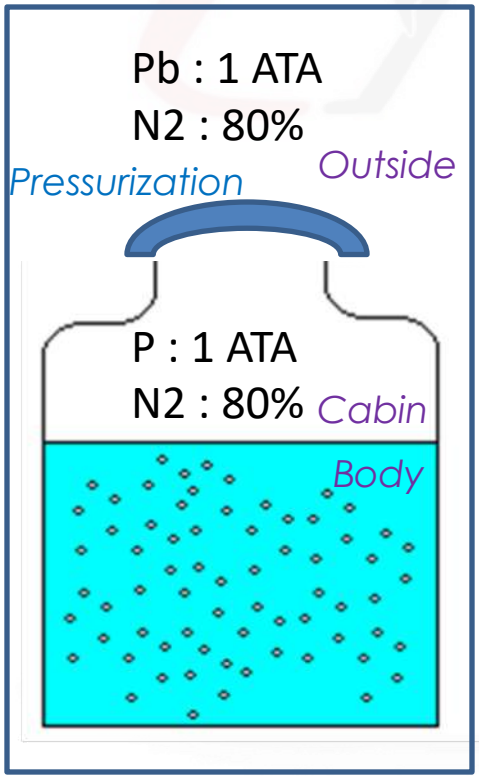
Decompression Illness (DCI)

ENVIRONMENTAL PATHOLOGIES

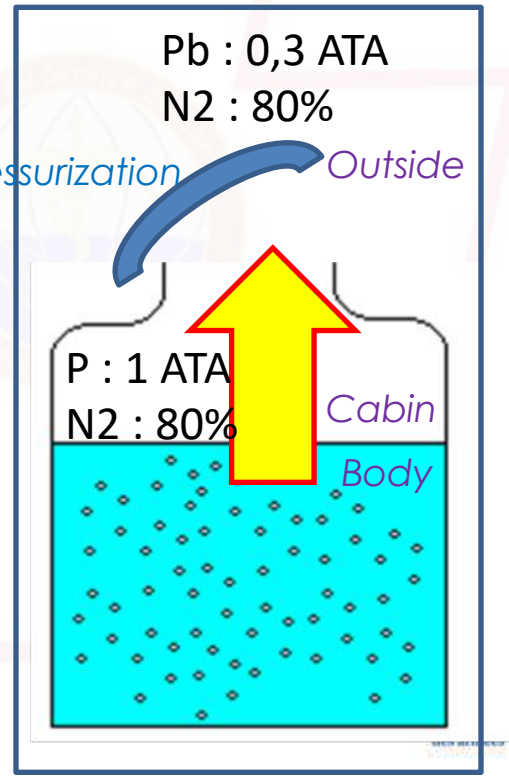
✓ **DECOMPRESSION ILLNESS DCI** – *Accident de Désaturation ADD*

On the ground
Pb : 1 ATA
N2 : 80%

FL 240 with unpressurizated cabin
Pb ↘ : 0,3 ATA
N2 : 80%



Gradient :
Pb ↘ : 1 ATA ➔ 0,3 ATA

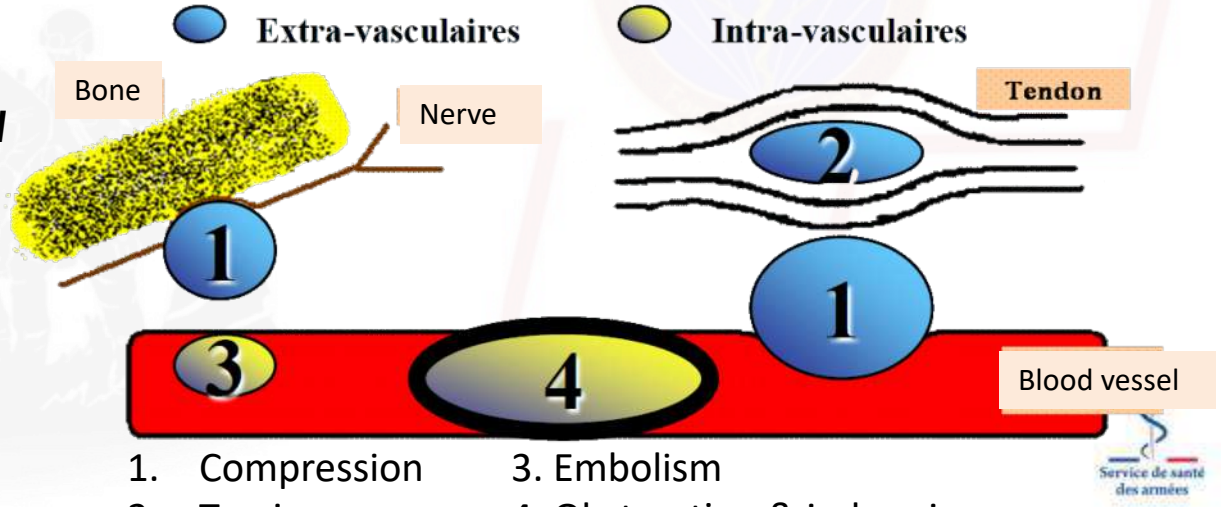


❖ Gas bubbles formation in Decompression Illness :

- Depend on speed of ascent & ↘ of ambient pressure (Pb)
- moving from body storage to outside via pulmonary exchanges

- N2 stocked in fat tissus (70%), bones, muscles & tendons
  - Fast migration from muscle & tendinous tissues
  - Longer migration (hours) from bones & fat tissue ➔ inside tissus trapped N2 bubbles & Venous Gas Embolism VGE (= DCS DC Sickness)
  - Abrupt depressurization : Arterial GE (if left-right shunt)
  - Local tissus inflammatory reactions

« Location of the bubbles and the character of the tissue involved determine the clinical presentations »



1. Compression
2. Tearing
3. Embolism
4. Obstruction & ischemic process

Pollock N, Updates in Decompression Illness, Emerg Med Clin N Am 35 (2017) 301–319

Table 1. Signs and symptoms of Altitude Decompression Sickness.

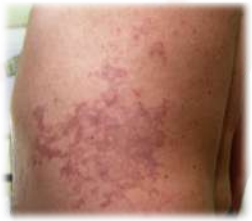
DCS Type	Bubble Location	Signs & Symptoms (Clinical Manifestations)
BENDS *60-70%*	Mostly large joints of the body (elbows, shoulders, hip, wrists, knees, ankles)	• Localized deep pain, ranging from mild (a "niggle") to excruciating. Sometimes a dull ache, but rarely a sharp pain. • Active and passive motion of the joint aggravates the pain. • Pain can occur at altitude, during the descent, or many hours later.
NEUROLOGIC Manifestations *10–15 %*	Brain	• Confusion or memory loss • Headache • Spots in visual field (scotoma), tunnel vision, double vision (diplopia), or blurry vision • Unexplained extreme fatigue or behavior changes • Seizures, dizziness, vertigo, nausea, vomiting and unconsciousness may occur
	Spinal Cord	• Abnormal sensations such as burning, stinging, and tingling around the lower chest and back • Symptoms may spread from the feet up and may be accompanied by ascending weakness or paralysis • Girdling abdominal or chest pain
	Peripheral Nerves	• Urinary and rectal incontinence • Abnormal sensations, such as numbness, burning, stinging and tingling (paresthesia) • Muscle weakness or twitching
CHOKES *<3 %*	Lungs	• Burning deep chest pain (under the sternum) • Pain is aggravated by breathing • Shortness of breath (dyspnea) • Dry constant cough
SKIN BENDS *10-15%*	Skin	• Itching usually around the ears, face, neck arms, and upper torso • Sensation of tiny insects crawling over the skin • Mottled or marbled skin usually around the shoulders, upper chest and abdomen, accompanied by itching • Swelling of the skin, accompanied by tiny scar-like skin depressions (pitting edema)

Altitude-induced Decompression Sickness

Pilot Safety Brochure

www.faa.gov/pilots/safety

Federal Aviation Administration



cutis marmorata

Risk factor : altitude, T° , duration, dehydration, OH, age, physical effort, BodyFat Ratio, diving

Delayed symptoms until 24h after exposition !!

Service de santé des armées

❖ Low prevalence of altitude DCI in airborne operations (1)

US experience since 1941 (>50 years) :

Type of Altitude Exposure				
		Chamber	Operations	unclear
1941-1976		131	14	
1977-1986		507	21	
1987-1999		437	42	1
Totals		**93%**	**7%**	

max **63** cases including Helicopter, aircraft except U2 **&** parachutists….

Butler et al, USAF Experience with Hyperbaric Therapy of Altitude Decompression Sickness (1941-1999) NATO RTO. 2001.

Scientific litterature : 2 cases report after repeated military Free Fall : 100% recovery

Petruso et al,Definitive Treatment of Neurological Decompression Sickness in a Resource Limited Location. Aerosp Med Hum Perform. 2021
Butler et al, Decompression sickness presenting as optic neuropathy. Aviat Space Environ Med. 1991

French experience since 1998 (>20 years) : 22 bends & 2 chokes

Service de santé des armées

❖ Why this low prevalence ?

- ↘ risk factor :

SoF : rustic & ultratrained military *(bodyfat ratio, dehydratation, threshold of physical activities and tiredness, age….)*

limited exposure until the drop

continuous descent after the drop (natural recompression)

under-declaration for benign DCI

TABLE II. MAJOR DIFFERENCES BETWEEN DIVING AND ALTITUDE DECOMPRESSION SICKNESS (100).

Altitude DCS	Diving DCS
1. Decompression starts from a ground level tissue N_2 saturated state.	1. Upward excursions from saturation diving are rare.
2. Breathing gas is usually high in O_2 to prevent hypoxia and promote denitrogenation.	2. Breathing gas mixtures are usually high in inert gas due to oxygen toxicity concerns.
3. The time of decompressed exposure to altitude is limited.	3. The time at surface pressure following decompression is not limited.
4. Premission denitrogenation (preoxygenation) reduces DCS risk.	4. The concept of preoxygenation is generally not applicable.
5. DCS usually occurs during the mission.	5. DCS risk is usually greatest after mission completion.
6. Symptoms are usually mild and limited to joint pain.	6. Neurological symptoms are common.
7. Recompression to ground level is therapeutic and universal.	7. Therapeutic chamber recompression is time limited and sometimes hazardous.
8. Tissue PN_2 decreases with altitude exposure to very low levels.	8. Tissue PN_2 increases with hyperbaric exposure to very high levels.
9. Metabolic gases become progressively more important as altitude increases.	9. Inert gases dominate.
10. There are very few documented chronic sequelae.	10. Chronic bone necrosis and neurological damage have been documented.

Space, and Environmental Medicine • Vol. 82, No. 5, Section II • May 2011 A5

Sheffield et al. Flying after diving guidelines : a review

Prevention of DCI ??? :

Medical and military selection

Limit bubbles formation

Limit risk factor

Service de santé des armées

ENVIRONMENTAL PATHOLOGIES

✓ **HYPERINTENSE WHITE MATTER HWM Lesions**

Neurology. 2013 Aug 20; 81(8): 729–735.
doi: 10.1212/WNL.0b013e3182a1ab12
PMCID: PMC3776459
PMID: 23960192

White matter hyperintensities on MRI in high-altitude U-2 pilots

Stephen McGuire, MD, Paul Sherman, MD, Leonardo [illegible], MD, MPH, Patrick Grogan, MD, John Sladky, MD, Anthony Brown, MD, Andrew Robinson, MD, Laura [illegible]wland, Elliot Hong, MD, Beenish Patel, BS, David Tate, PhD, Elaine S. Kawano, BA, Peter Fox, MD, and Peter Kochunov, PhD

NO TOPIC FOR PARACHUTISTS

« The United States Air Force (USAF) operates the U-2 high-altitude reconnaissance aircraft, which maintains a cabin ***altitude of approximately [illegible] m (28,000–30,000 ft) while operating above 21[illegible]m. » … (during long hours…)***

Service de santé des armées

MEDICAL REGARDS

✓ TREATMENT

- **O2 100% +++**
- **Cabin Pressurization or aircraft emergency descent**
- **Ground level oxygen**
- Complications treatment

} recovery 90%

If failure…

- **Hyperbaric Oxygen**

Evacuation to facility under 1000ft

recovery > 95%

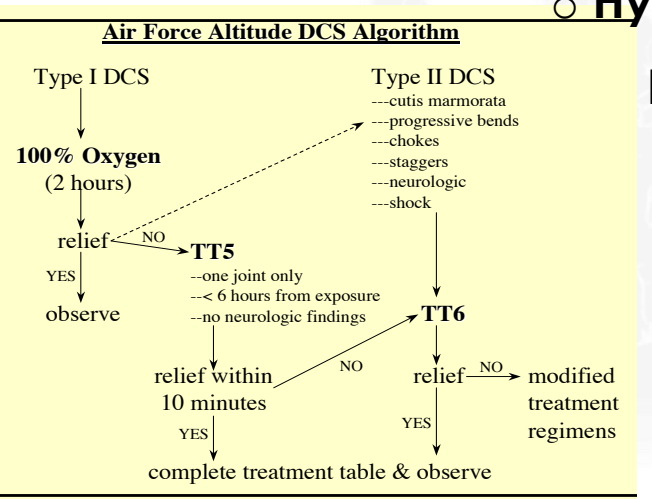


Fig. 8. A hyperbaric stretcher being loaded onto a helicopter. (*Courtesy*

MEDICAL REGARDS

✓ PREVENTION

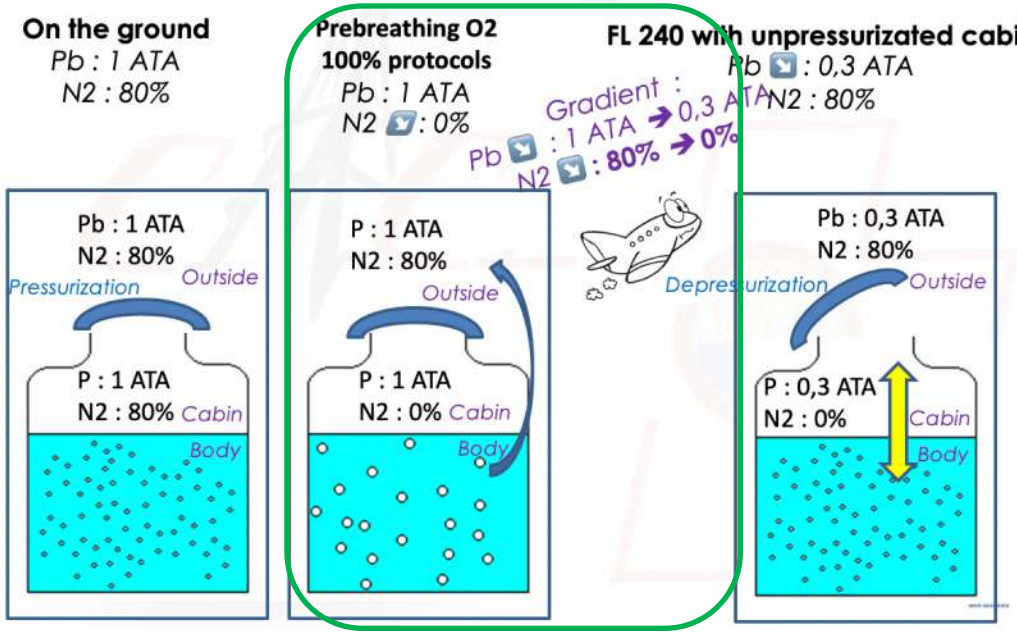
- ✓ Medical selection
- ✓ Military selection : training
- ✓ Continue medical monitoring
- ✓ Education about risk & pathologies

NATO STANAG 7056 Procedures

- ✓ Limit unecessary exposition
- ✓ Time between repeated expositions
- ✓ Pressurized cabin until the latest

- ✓ O2 providing above FL120 (training) or FL140 (operation)

- ✓ Prebreathing O2 100% above FL180



Wash out enough N2 from the tissues breathing pure O2 without N2 before depressurization to prevent DCI

Jha, Supplemental Oxygen for Paratroopers and Sky Divers Defence Science Journal, 2012

vs PRECAUTIONARY PRINCIPLE vs TYRANNY OF STANDARDS

✓ ADAPT PROTOCOLS

NATO STANAG 7056 Procedures

- ADRAC Altitude DCS Risk Assessment Computer : validated tool to estimate the risk of DCS with a range of variables. **Laboratory research +++**

Pilmanis et al, Operational medical issues in hypo- and hyperbaric conditions. Altitude decompression sickness risk prediction research internet. Defense Technical Information Center Compilation Part Notice, 2018.

✓ DON'T BLOCK A RISKY TACTICAL CAPABILITY & WELL ANALYSE

- Very few concerted scientific studies
- Rare « real » cases, low prevalence for rich theoric literature
- Differentiate standards for pilot and parachutists : **not the** same population / flight plan / exposure / missions & consequencies if sick
- Evaluate the risk of oxygen equipment in parachuting (weight, discomfort, fatigue, visual field) with regard to the expected benefit

THE LESS IS MORE

Service de santé des armées

CONCLUSIONS

Accept risky activities for tactic/strategic capabilities

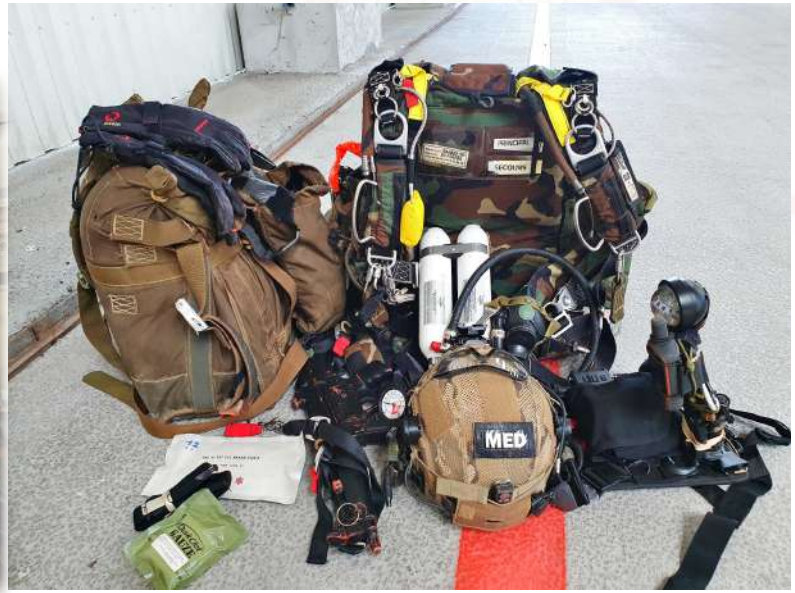
➔ Monitoring principle instead of prevention principle

Involve « ground » physicians & HAHO qualified professional ++

Choose acceptable risk with EBM

Prepare PACE plan with MEDEVAC plan & locate HBO facility available

Take O2 supply +++



Service de santé des armées

QUESTIONS ?

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